PERFORMANCE OF IMAGE REGISTRATION-BASED INSTRUMENT PLACEMENT FOR PIXL. K. Wu[1,2], G. B. Doran[2], D. R. Thompson[2], A. C. Allwood[2], D. T. Flannery[2], R. F. Sharrow[2], D. A. K. Pedersen[3], C. C. Liebe[2], [1]Massachusetts Institute of Technology, [2]Jet Propulsion Laboratory, California Institute of Technology, [3]Technical University of Denmark.

Introduction: A key part of the Mars 2020 Rover's mission involves determining Mars's past ability to support life by characterizing spatially-resolved microscale elemental chemistry of geological targets. The mission will accomplish this using PIXL (Planetary Instrument for X-Ray Lithochemistry), an X-ray fluorescence spectrometer mounted on the rover's Instrument Deployment Device [1]. PIXL requires precise placement relative to the target surface, which would traditionally require multiple rounds of communication between the rover and Earth due to arm thermal expansion and kinematic errors, causing delays and lost opportunities for acquiring data [2]. Because Mars 2020 will have limited time to acquire data at each site, automation of instrument placement has the potential to greatly increase the science yield from the mission [3]. Moreover, closed-loop servoing onboard the spacecraft will permit precision placement to tolerances that would not otherwise be achievable due to the natural thermal expansion and contraction of the rover arm between communication cycles. This high precision will be critical for taking full advantage of the PIXL spatial resolution of ~100μm. A new algorithm for closed-loop instrument placement using image registration on context images, photos of the location and orientation of the instrument, has been developed and tested on images from previous Mars missions [2]. This paper presents a performance analysis evaluating the application of this algorithm to PIXL images under Mars-representative imaging conditions in order to inform mission design and predict system-level performance.

Method: To collect a representative image data set for testing the algorithm, we imaged Mars-representative rocks using a realistic testbed designed to accurately simulate the essential features of flight hardware, including a PIXL context camera, illumination, optics, and imaging geometry. The test data set assumed no dust deposition on the camera lens. We simulated rover slippage by translating the rock and camera relative to each other with precision linear stages. Images were acquired in 0.5 cm steps over a 2.5 cm range in three axes. We also acquired images at standoffs greater than optimum (2.5 cm), which may occur during instrument placement or when imaging targets with high surface relief.

The algorithm must also perform under changes in solar illumination. For simulating Martian nighttime, we placed the instrument in a dark room with the camera's flash as the only source of illumination. For worst-case daytime lighting, the field of view was exposed to simulated Mars solar illumination parallel to the surface of the target. Registrations across these two conditions test the robustness of the algorithm to illumination angle and intensity changes.

Image targets included natural and abraded surfaces of representative rock samples. Both natural and abraded surfaces will be potential targets of interest on Mars.

Figure 1. Examples of rocks imaged.

Analysis: We established a ground truth homography by manually matching points in each pair of images to derive a homography matrix. This was done for each pair of images with 0.5cm translation between them. For pairs with greater translations, the ground truth was obtained by chaining the homographic transformation for image pairs to calculate a cumulative translation. To ensure that small errors did not accumulate, we spot checked some of these cases visually.

We then applied the flight code algorithm to pairs of the collected images to automatically determine homography matrices in a manner similar to what would occur during closed-loop operation onboard the rover. After using the algorithm-generated homography to transform randomly selected points in the source images, we compared the automatic solutions to the manual solutions for quantitative performance statistics.

Using the differences between the selected point coordinates, we estimated the 3σ error bound of the algorithm over the different conditions. Our performance model will help inform operations planning and make recommendations for use of the algorithm. The

PIXL instrument placement approach represents an evolutionary technology advancement and has outsized significance, both for improving data collection efficiency and for enabling placement precision superior to that achieved in any prior mission.

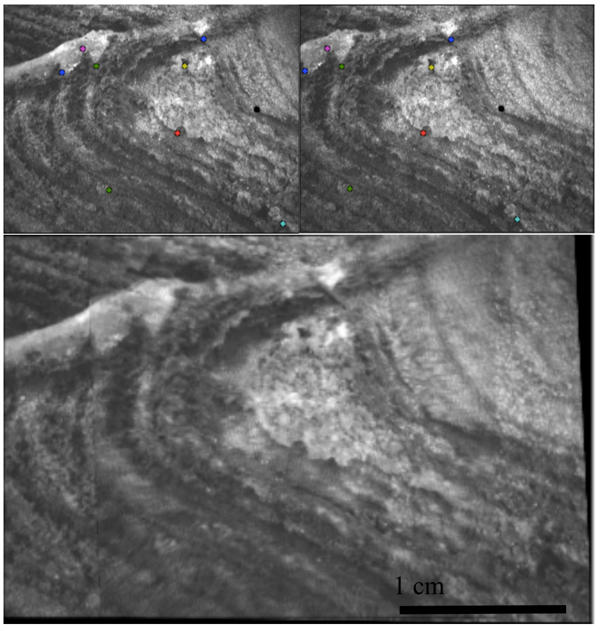

Figure 2. Two test images (top) of a grooved rock, merged (bottom) using manual point matching for establishing ground truth.

References: [1] Allwood A. C. et al., (2015) *IEEE Aerospace Conference*., 1-13. [2] Doran G. et al., (2016) *International Joint Conference on Artificial Intelligence*. [3] Thompson D. R. et al., (2015), *Astrobiology,* 15(11), 961–976.